NAVAL AVIATION SYSTEMS TEAM

JTEG MEETING AT LIMA ARMY TANK PLANT 24-26 JULY 2001

NAVAL AIR SYSTEMS COMMAND RESEARCH & ENGINEERING

FOREIGN COMPARATIVE TEST PROGRAM ON "RUSSIAN EROSION RESISTANT COATINGS FOR US NAVY GTE COMPRESSORS"

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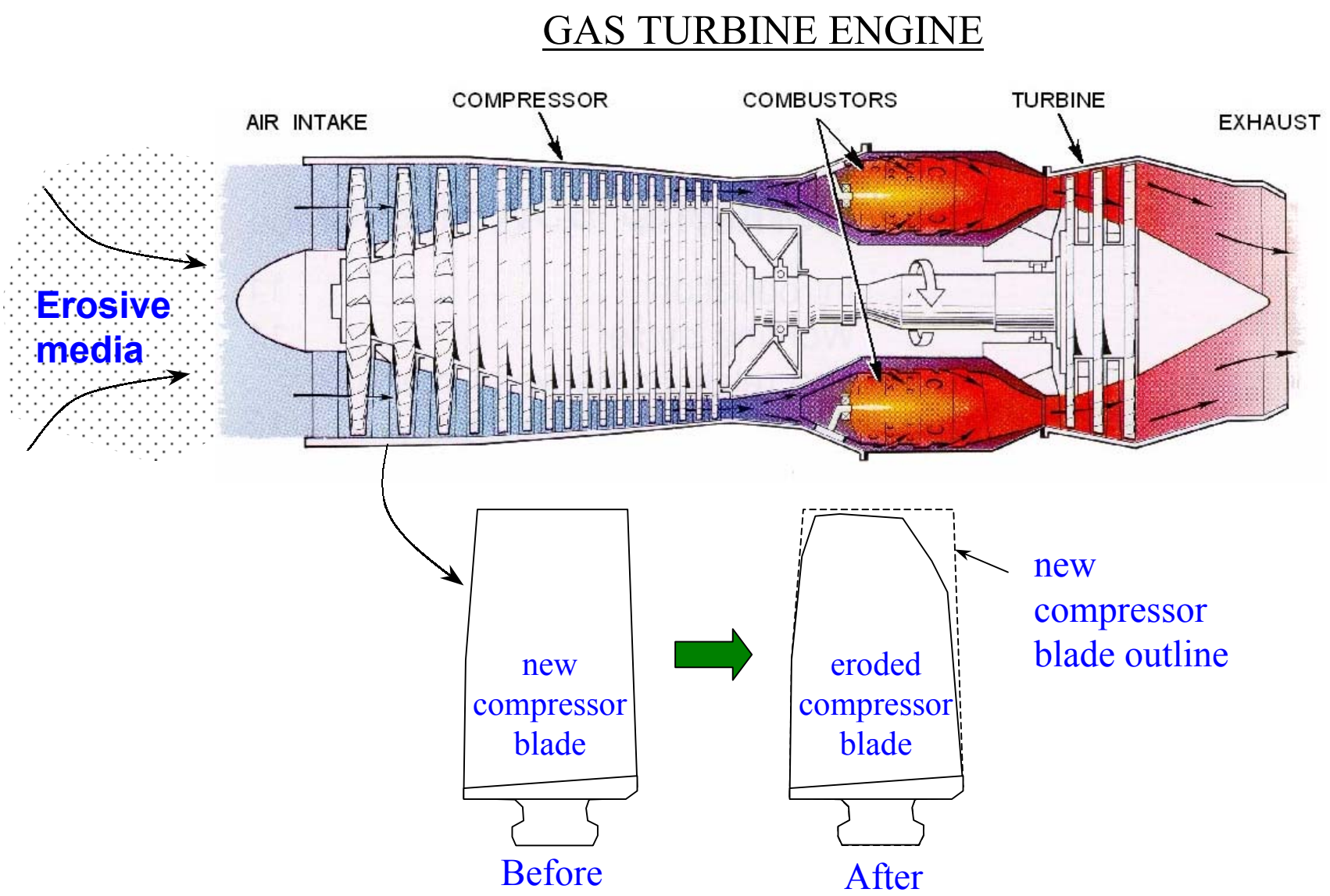
OUTLINE

- The US Navy Problem
- The Russian Coating
- The FCT Program
- Testing
- Test Results
- Program Status
- Acknowledgment

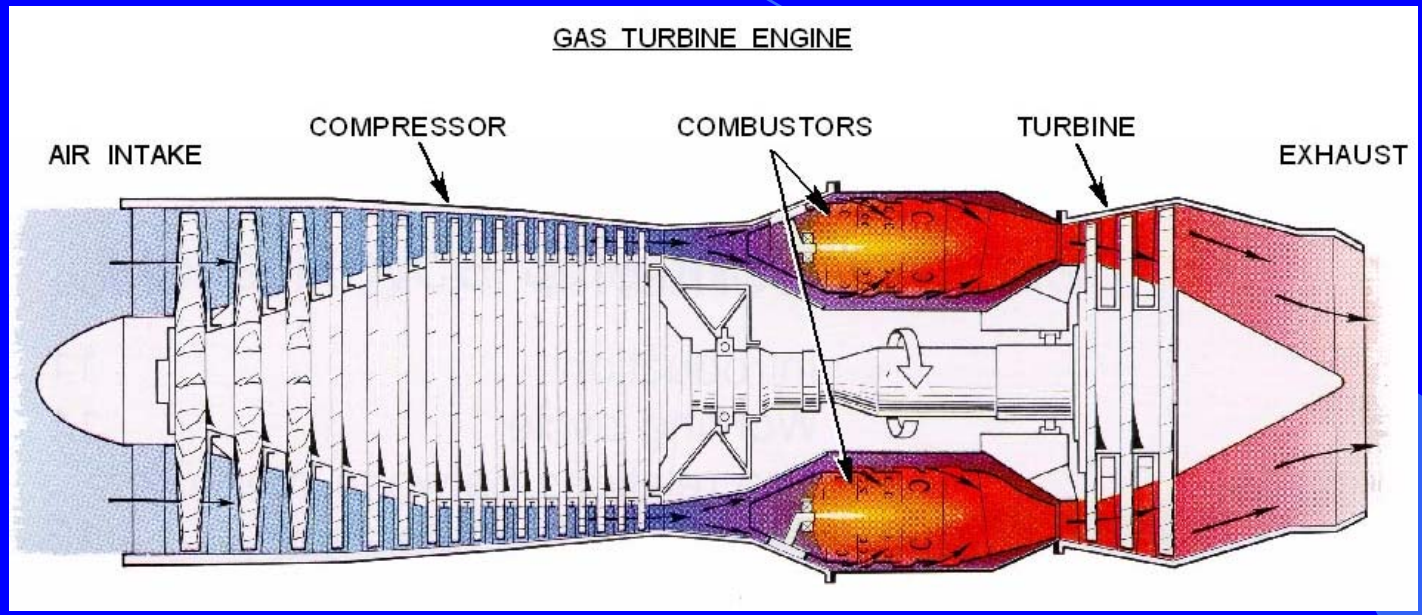
“The Problem”

“The Problem”

“The Problem”


GAS TURBINE ENGINE
AIR INTAKE
COMPRESSOR
COMBUSTORS
TURBINE
EXHAUST
Erosive media
new compressor blade
eroded compressor blade
new compressor blade outline
Before
After

Chain Reaction



- Particle size downstream
  - Surface hardness
  - Mix of sand & metal
- Increase in combustor and hot section damage
- Worst case operation at take-off & landing
  - high temperature
  - high speed (air/rotor)
  - high sand ingestion rate

Erosion Resistant (ER) Coating

Initially developed by PRAD to protect the TV2-117 engine compressor which experienced severe erosion damage

- Afghanistan conflict
- Western Siberia Operation (1000 aircraft)

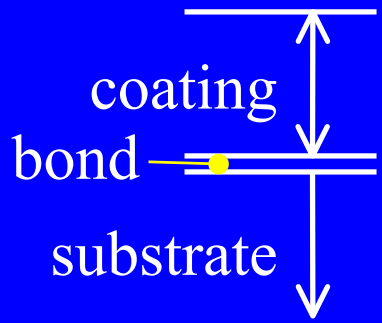
Coating in TV2-117 Engine

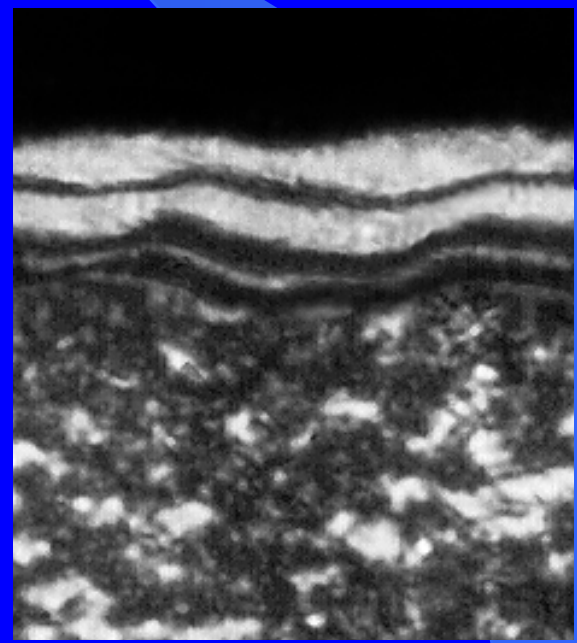
ER Coating Design Target

- Designed to prevent compressor erosion under operation in erosive media
  - Sand / desert
  - Dust / dirt
  - Volcanic ash
- Other Design Goals
  - Corrosion resistance
  - Designed for environment

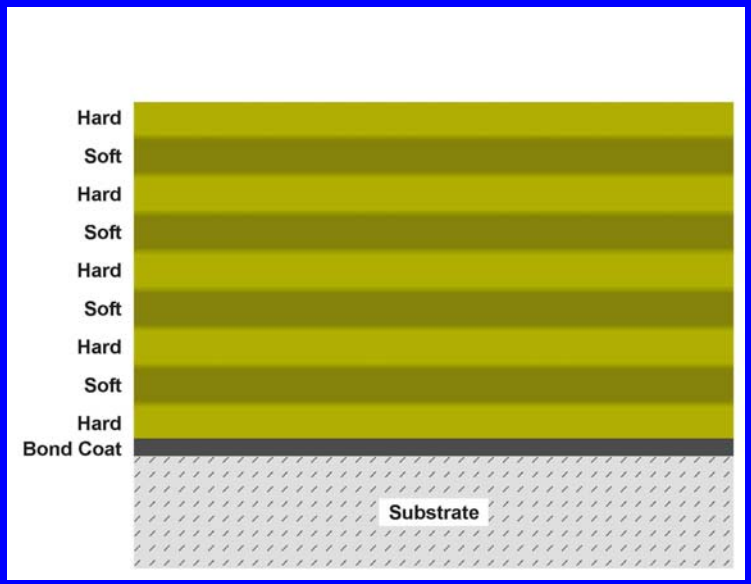
ER Coating Description

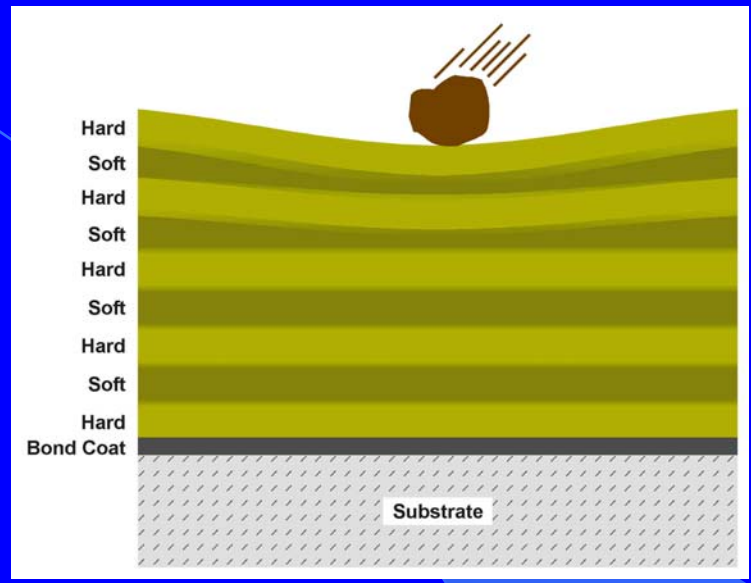
- Coating Description
  - ∗ Bond Coat (metallurgical)
  - ∗ Multi-layer
  - ∗ TiN… but a lot more
  - ∗ thickness 5-20 μm
  - ∗ hardness 2800-3200 Vickers
  - ∗ operating temperature range : -60°C to +600 °C

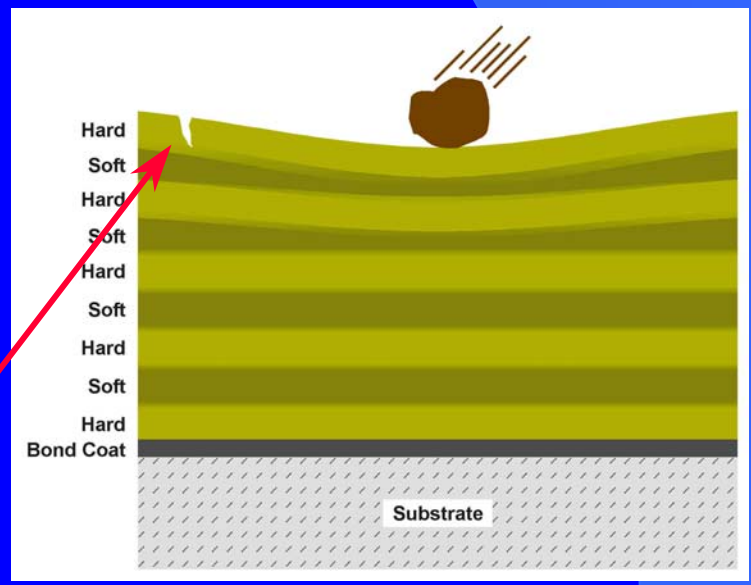




ER Coating Mechanics





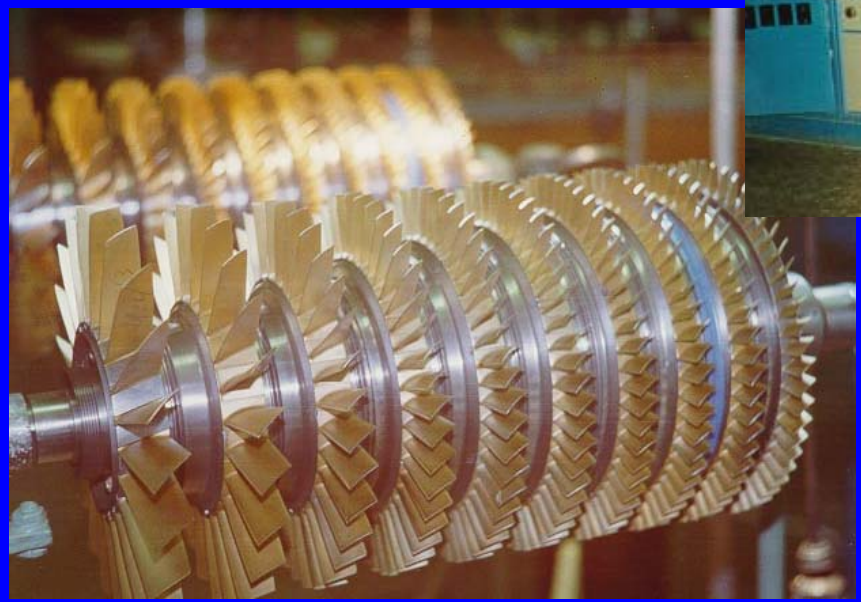


coating is tolerant to a crack initiation site

ER Coating Application Method

- Preparation / pretreatment
- Coating by CAPVD
  - * proprietary process
- SVT (vibro-treatment)

Coating Machines

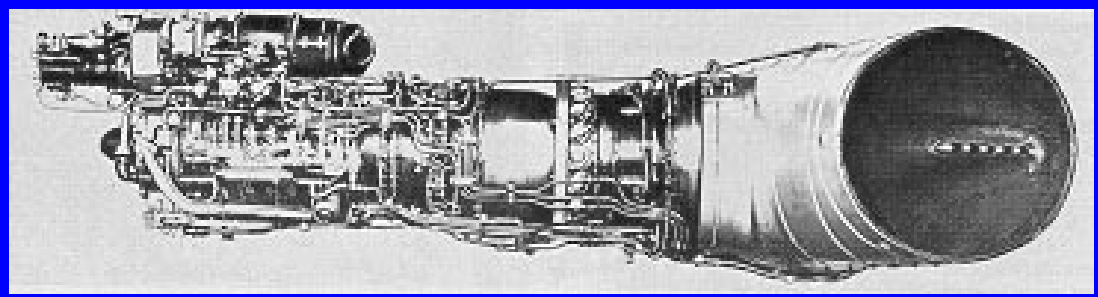


Coated Compressor Rotor

ER Coated Engines

- TV2-117
  - turboshaft
  - 1,500 shp
  - flying on MI-8 Helicopter

MI-8



ER Coated Engines

- TV3-117
  - turboshaft
  - 2,200 shp
  - flying on MI-8MTV, MI-17, MI-24, MI-28, KA-32, KA-50, KA-52

TV3-117 Engine

MI-24

MI-28

ER Coated Engines

- NK-16ST
  - industrial version of NK8-2U Aero Engine
  - 16,000 shp
  - Mechanical drive for gas compressor station
- Industrial TV2-117M
  - Dual TV2-117
  - Electric Power & heat

NK-8-2U

ER Coated Engines

- PS-90
  - Turbofan
  - 35,000 lbf thrust
  - Flies on Il-96

PS-90

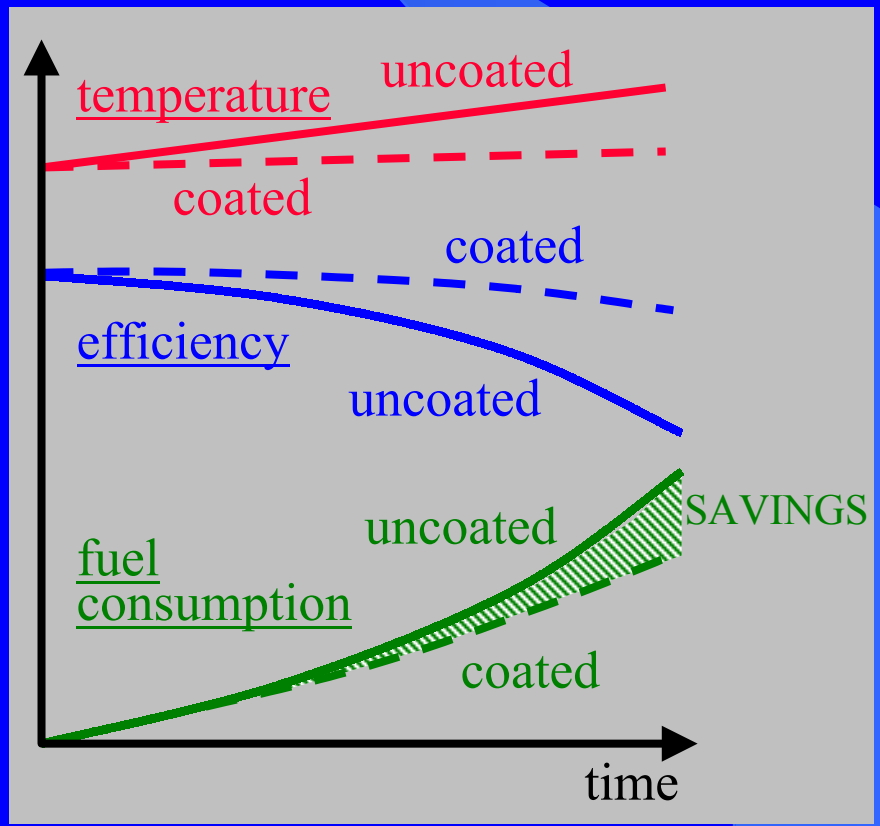
Il-96

ER Coating TV2-117 Service Performance

Description	Non-Coated	Coated
Rate of premature engine removal due to erosion	20-45%	0%
Rate of blades/vanes rejected due to erosion	70-80%	2-3% (mostly due to FOD)
Engine performance debit at overhaul	10-30%	<3%

ER Coating Benefits

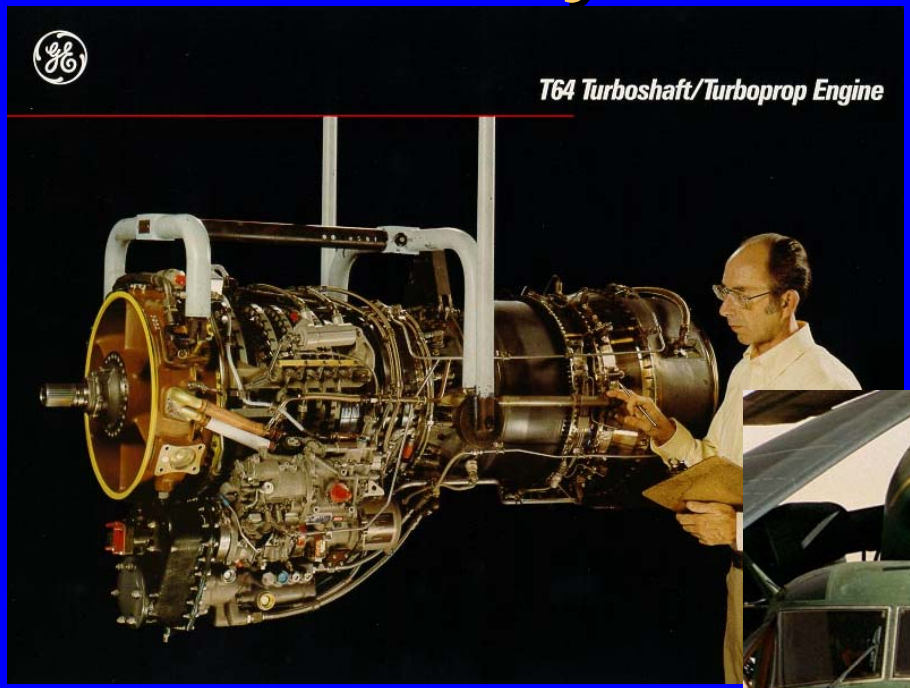
- Safety and Reliability increase of engine and aircraft
  - Less increase in operating exhaust gas temperature
  - Less vibration degradation
- Operational advantages
  - Less degradation of engine efficiency over operational cycle
  - Lower fuel consumption (≈ 10-15%)
  - Extended service life (≈ 30%)



ER Coating Benefits (cont'd)

- Operational Readiness
  - Longer on-wing time (less premature removal)
  - Less downtime of aircraft
- Fewer spare engines required
- Lower Repair and Overhaul costs
  - Fewer shop visits
  - Lower cost of spare/replacement parts
    - Compressor components
    - INCLUDING HOT SECTION COMPONENTS

US Navy Lead FCT Program



T64 Engine

H-53

FCT

Foreign Comparative Testing Program

Erosion Resistant Coating Program

Team Members

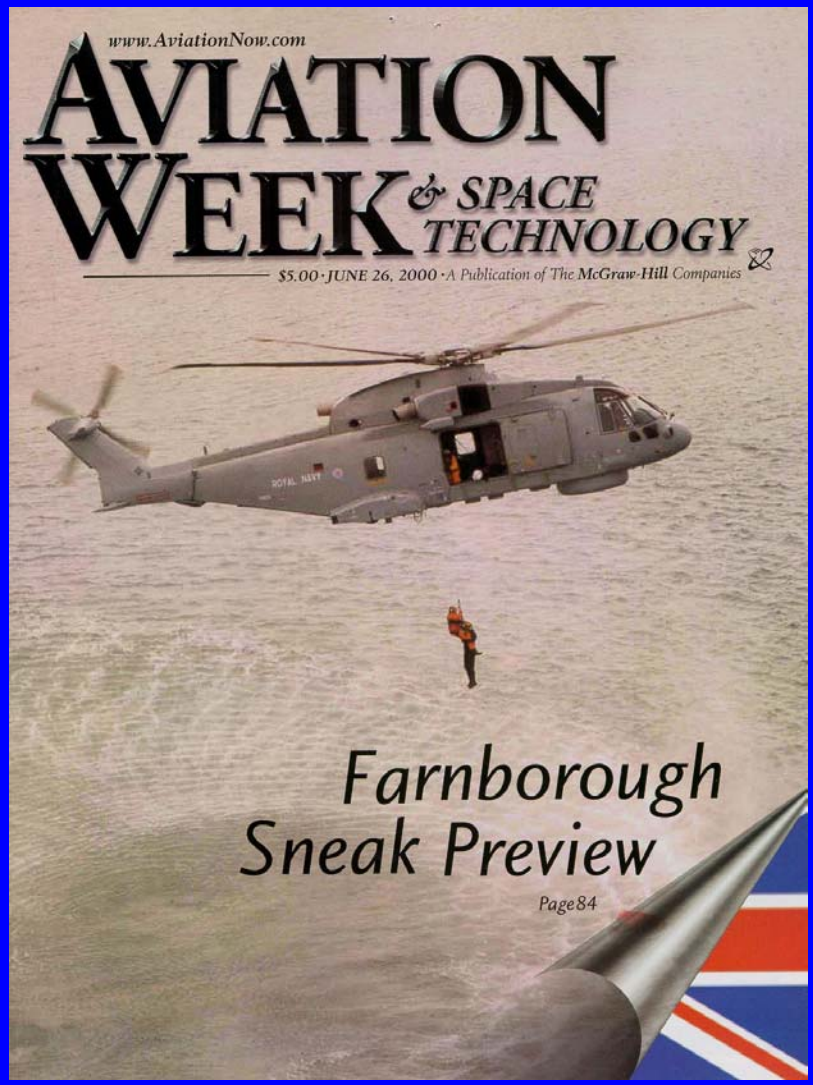
Joint Venture

Canada

Russia

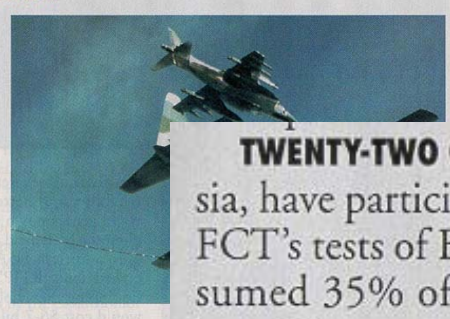
Update

26 June 2000



U.S. Plans To Test 11 New Foreign Military Systems

PHILIP J. KLASS/WASHINGTON



The Pentagon has chosen 11 promising defense products or systems developed by non-U.S. companies to be evaluated under its Foreign Comparative Testing (FCT) program.

The products range from a high-power klystron tube developed by the U.K.'s Thorn TMD, which could enhance the reliability of the E-3 AWACS radar, to a vehicle intended to deactivate land mines, developed in South Africa.

Testing will continue in Fiscal 2000 on many of the items selected in 1998-99, including a wing pod for MC-130H Combat Talon aircraft to refuel helicopters, which was developed by Flight Refueling

TWENTY-TWO COUNTRIES, including Russia, have participated in the test program. FCT's tests of British products have consumed 35% of FCT's funds during the last 20 years, followed by Germany (15%), and France and Sweden—each with 11% of the total. Funds for new FCT programs for Fiscal 2000 total nearly $13 million. Ongoing test programs from Fiscal 1998-99 are funded for $17.8 million, for a combined total of approximately $30.8 million.

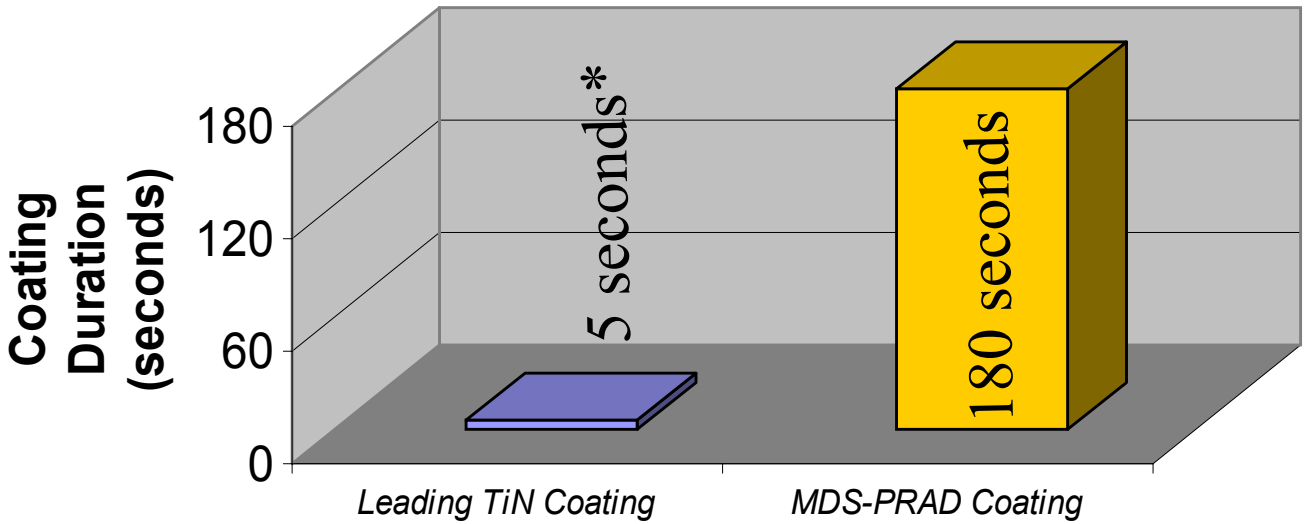
Russian technology undergoing evaluation includes a titanium-nitride coating for jet engine compressor blades intended to enhance their resistance to ingested debris. The coating was developed by Russia's PRAD. The tests, which involved ingestion of more than 16 lb. of sand during 15 hr. of engine operation, indicated that titanium-nitride coated blades suffered significantly less degradation, according to FCT's recent report.

Program History

- T64 engine experiencing erosion problems
- Problems accentuated during Desert Storm
- US Navy investigated several abatement solutions, including several coatings
- MDS-PRAD provided samples of coating to US Navy for evaluation

Program History

- Comparison test to MDS-PRAD sample (duration of coating under erosive test)

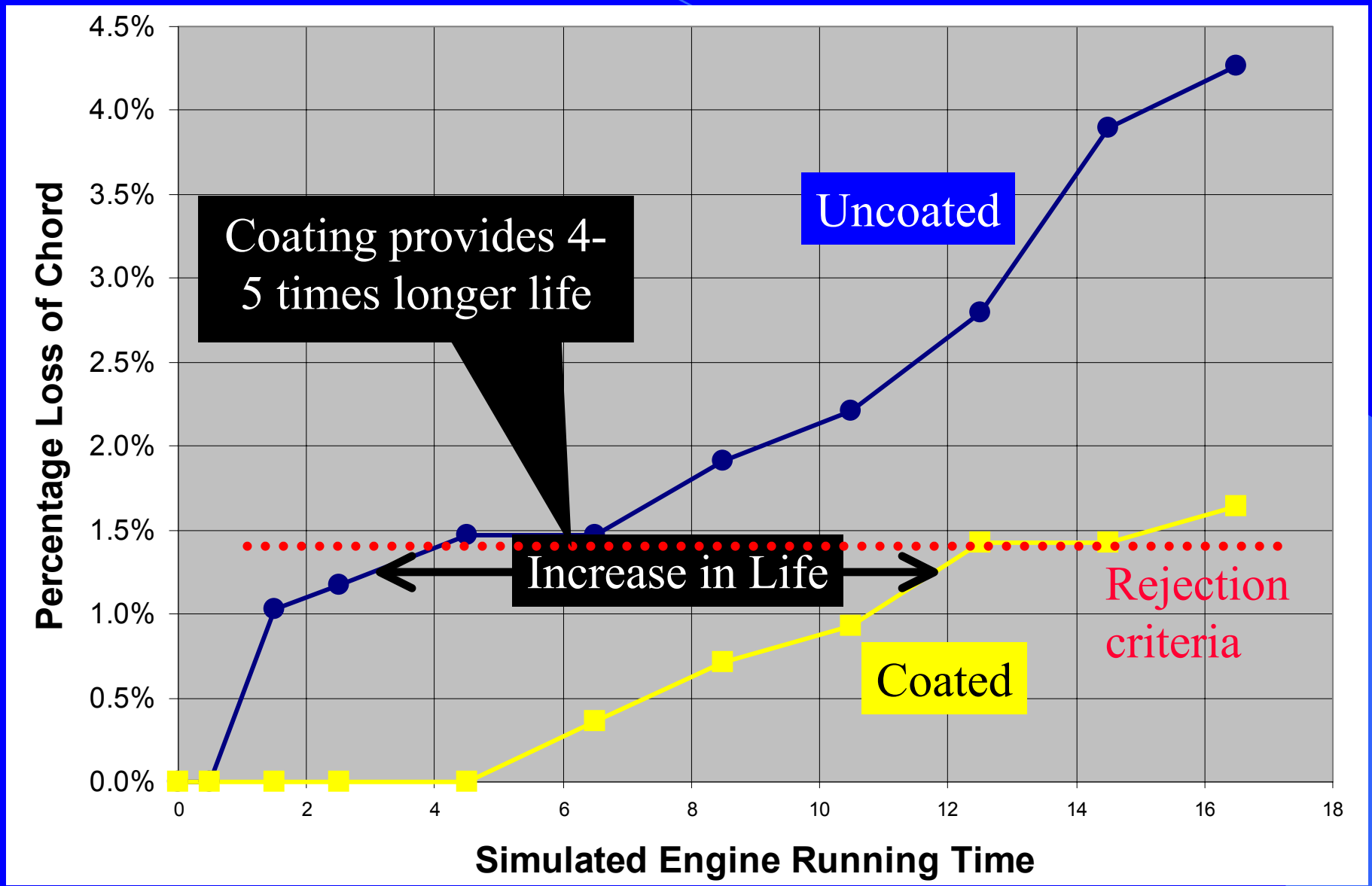


Duration of coating on coupon tests performed by the US Navy. Abrasive sand test at 90° impingement angle. *In addition, the MDS-PRAD coating was exposed to sand at seven times the rate of a leading TiN coating. Conclusion: MDS-PRAD coating is orders of magnitude better than any other coating system to guard against erosion.

Participants in FCT

- US Military FCT Program Office
- US Navy
  - NAVAIR Patuxent River
  - NADEP Cherry Point
  - Naval Research Laboratories Washington
- Kirtland Air Force Base
- General Electric Lynn
- University of Cincinnati
- Metcut Research Inc.
- Ural Work of Civil Aviation (PRAD)
- MDS Aero Support Corporation
- Defence Contract Management Command Americas (DCMC)
- Canadian Commercial Corporation (CCC)
- Public Works and Government Services of Canada (PWGSC)

Erosion Test



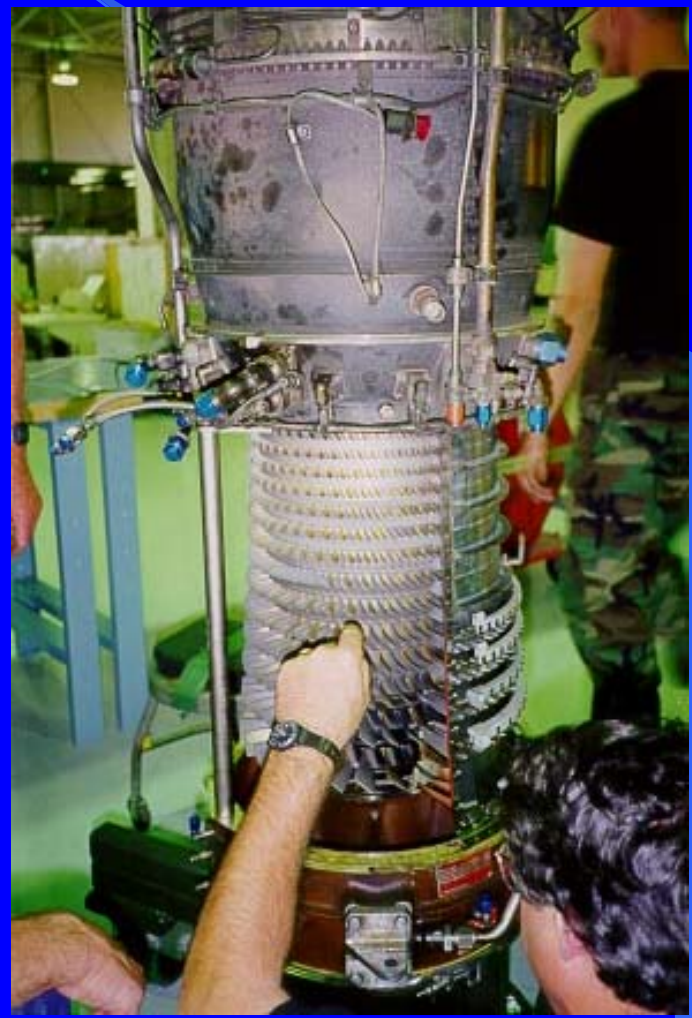
T64 Engine Test Kirtland AFB

T64 Engine Test

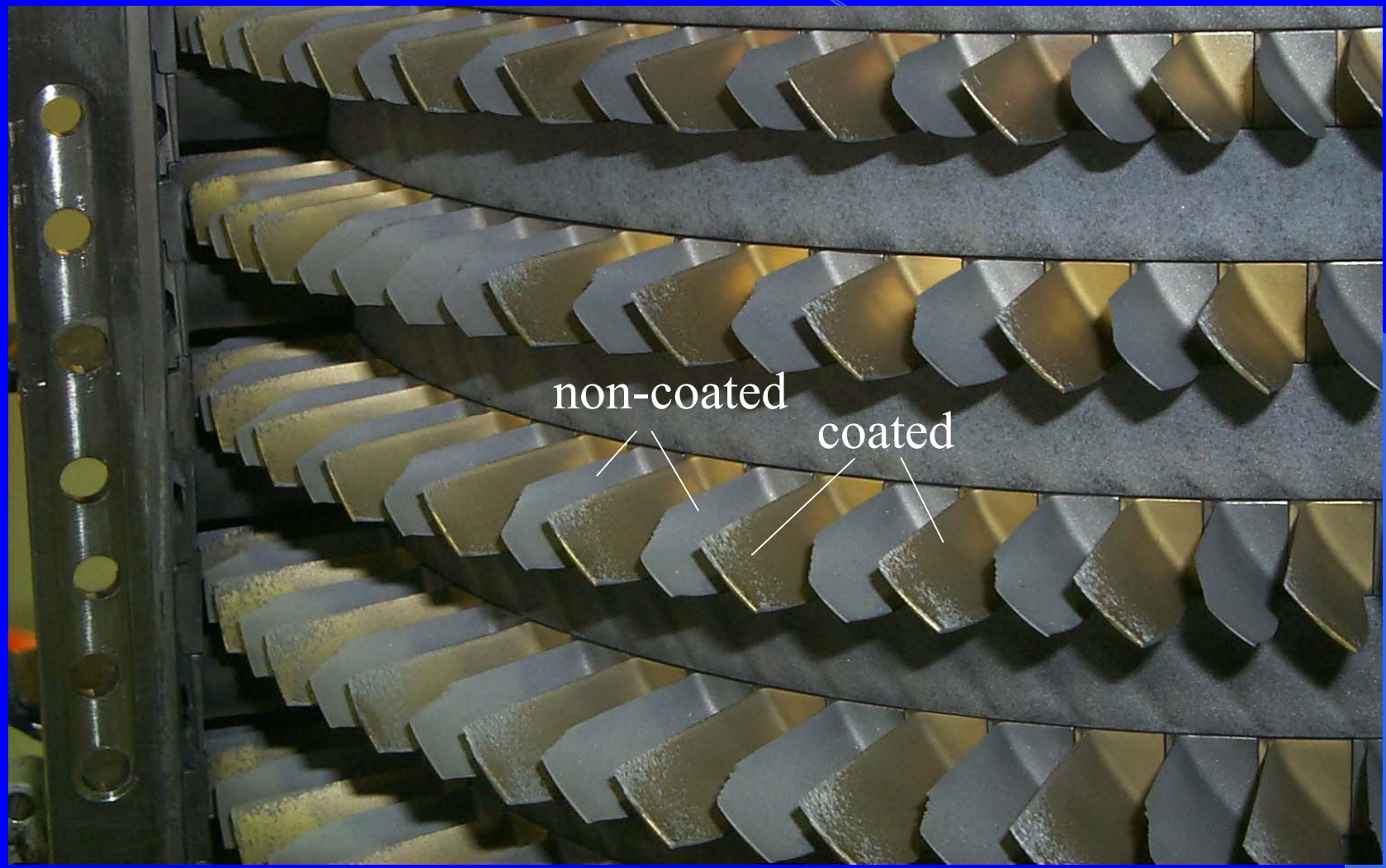
- Rainbow pattern
- Sand 100-200 micron
- Engine ran until 25% loss in power

T64 Engine Test

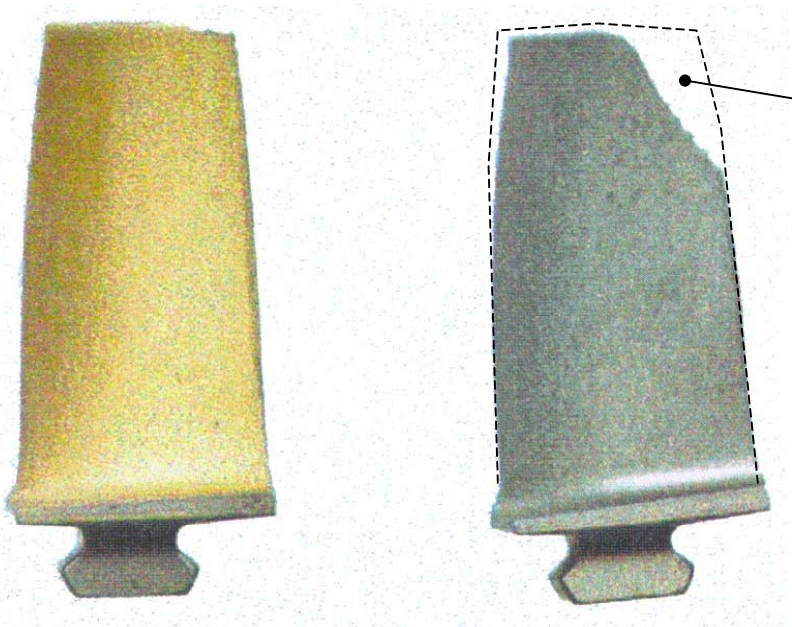
- Engine opened
- Blades and vanes removed
- Measurements
  - Vernier
  - Diffracto



T64 Engine Test Results

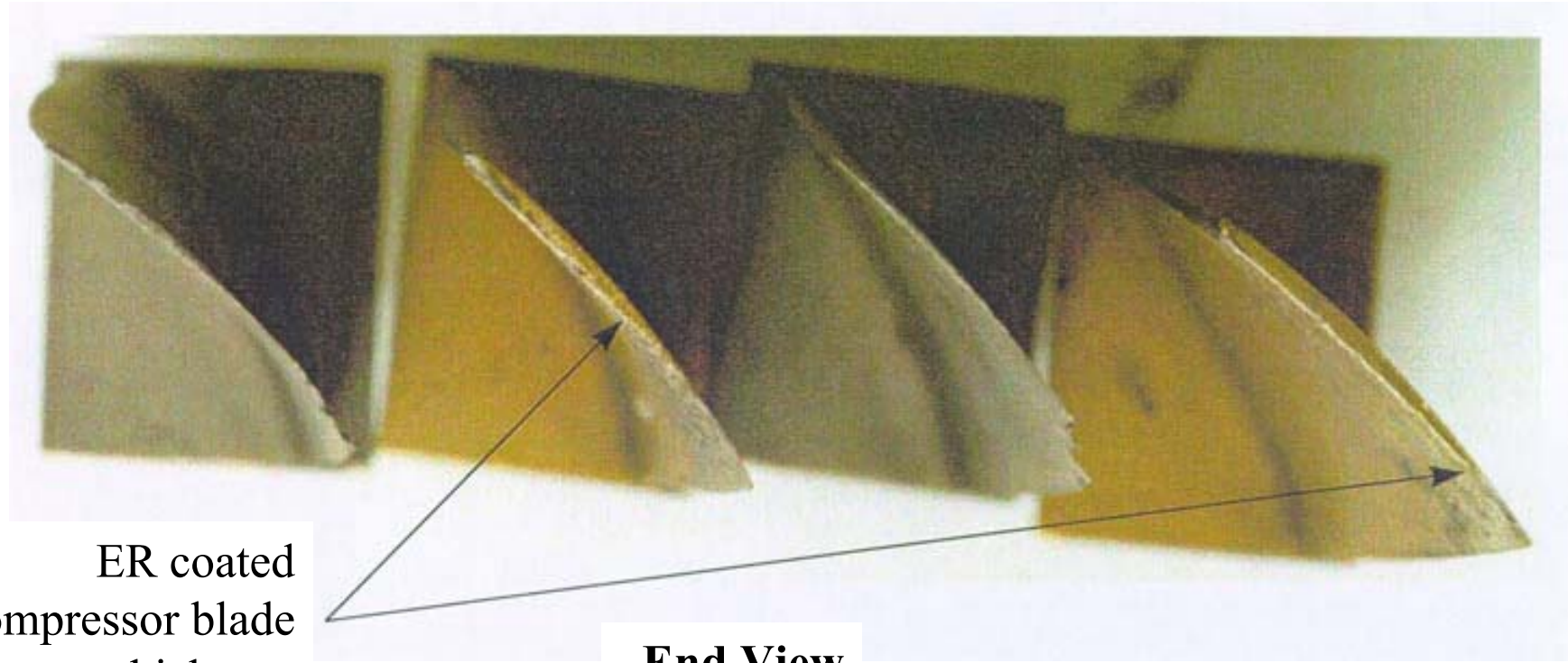


T64 Engine Test Results



Results of T64 engine sand ingestion test
conducted by GE and US Navy

T64 Engine Test Results



ER coated compressor blade thickness preserved

End View

Results of T64 engine sand ingestion test conducted by GE and US Navy

T64 Engine Test Results

- GE Conclusion on Erosion Performance and Leading Edge Protection
  - ∗ Coat all blades stage 1 through 14
    - Improvement on chord and thickness of the blades: up to 8 X
  - ∗ Coat all vanes stages 1 through 13
    - Improvement on chord and thickness of the vanes: up to 17 X

T64 Engine Test Results

- GE Conclusion on "Other" requirements:
  - Operating temperature range: Acceptable
  - Coating Thickness: Acceptable
  - Airfoil distortion: Acceptable
  - Surface finish Acceptable
  - Corrosion resistance Acceptable
  - Area coated Acceptable

FCT Program Status

- MDS-PRAD Coating Facility in Montreal

Erosion Resistant Coating Applications

Jets

Transports

Helicopters

Ground Vehicles

Acknowledgment

- Phil Rodger

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